OPTICAL BURST SWITCHING IN WDM RING NETWORKS

A Thesis Submitted For The Partial

Fulfilment Of Requirements For Degree Of

Bachelor Of Technology
In
Computer Science and Engineering

BY

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DEPARTMENT OF COMPUTER SCIENCE AND ENGINEERING

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CERTIFICATE

This is to certify that the thesis entitled, "**Optical Burst Switching in WDM Ring Networks**" submitted by Mr. Swapnajeet Padhi (108CS018) in partial fulfilment of the requirements for the award of Bachelor of Technology Degree in Computer Science and Engineering at National Institute of Technology, Rourkela is an authentic work carried out by him under my supervision and guidance.

To the best of my knowledge, the matter embodied in the thesis has not been submitted to any other University/Institute for the award of any Degree or Diploma.

Prof. A.K. TURUK

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Date:

Place:

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Last, but not the least, I would like to dedicate this thesis to my family, for their love, support, patience, understanding and guidance.

Swapnajeet Padhi

(108CS018)

ABSTRACT

Optical Burst Switching (OBS) is being envisaged as the next generation switching technology to transmit Internet traffic directly over WDM networks with a fine granularity between Optical Circuit Switching (OCS) and Optical Packet Switching (OPS). It has higher bandwidth-efficiency than OCS. OBS is usually characterized by burstification, burst header packet (BHP) generation and data burst (DB) transmission. The burst header packet is transmitted first by the source to the destination followed by the data burst. Each intermediate node processes the header electronically so that the data burst corresponding to that BHP is transparently switched without requiring any O/E/O conversion. This unique feature of OBS requires a strict coordination between DB and BHP and thereby making it a challenging task. OBS has been implemented in WDM ring networks for FT-TR (Fixed tuned Transmitter and Tunable Receiver) systems and TT-FR (Tunable Transmitter and Fixed tuned Receiver) systems. In FT-TR systems, the number of channel and destination collisions is higher whereas there is no source collision due to the fixed tuned nature of the transmitter. In TT-FR systems the number of channel collisions is large as multiple nodes communicate using the same channel but there is no destination collision. In this work I have implemented OBS in WDM ring networks for TT-TR (Tunable Transmitter and Tunable Receiver) systems. It has been shown that the proposed protocol is free from source and channel collisions, as well as reduces destination collision to a greater extent. The tunable transmitter and tunable receiver node architecture has been described. We compared the performance of TT-TR system with that of TT-FR system with respect to number of packets lost, average queuing delay and average propagation delay. It is found that the proposed protocol is more effective in avoiding collisions than the TT-FR.

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CHAPTER 1

INTRODUCTION

1.1 INTRODUCTION

Internet explosion and the use of Internet for carrying large amount of multimedia information has lead to an unprecedented increase in the demand for high speed and higher bandwidth telecommunication networks. So the need of the hour is to develop high capacity networks capable of catering to such demands. This has lead to the development of optical wavelength division multiplexed network that are mainly used for backbone networks and MANs. In these optical WDM systems, speed to the extent of 50 Tb/s per fibre is achievable. Each optic fibre has several data channels. Each channel operates at a different frequency. Figure 1.1 depicts the evolution of the different optical transmission methodologies

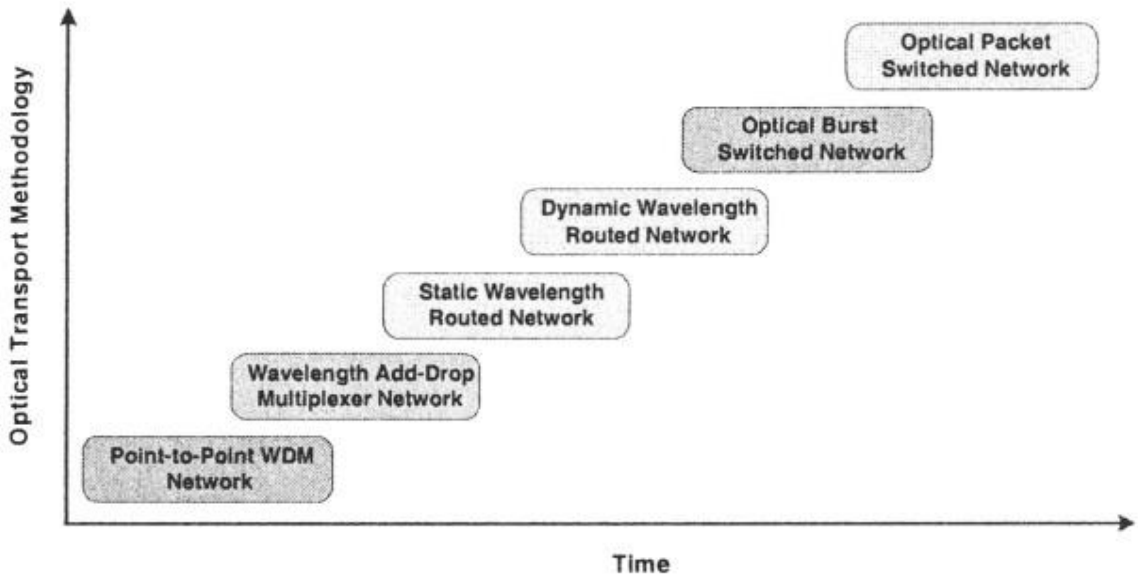

Fig1.1 Evolution of optical transmission methodologies [1]

Table 1.1 compares the three different all-optical transmission paradigms. It is evident that Optical Burst Switching (OBS) offers a fine granularity between Optical Circuit Switching (OCS) and Optical Packet Switching (OPS).

OPTICAL SWITCHING PARADIGM	BANDWIDTH UTILIZATION	SET UP LATENCY	SWITCHING SPEED REQ.	PROC./SYNC OVERHEAD	TRAFFIC ADAPTIVE
OPTICAL CIRCUIT SWITCHING	Low	High	Slow	Low	Low
OPTICAL PACKET SWITCHING	High	Low	Fast	High	High
OPTICAL BURST SWITCHING	High	Low	Medium	Low	High

Table 1.1 Comparison of the different all-optical network paradigms [1]

1.2 Optical Burst Switching

In OBS transmission takes place for a group of packets assembled into a unit called data burst (DB). This process of assembly is called Burstification. After burstification, a control packet is generated for each DB carrying all the control information. This control packet is transmitted first to reserve resources for the DB. After some time called Offset time, the DB is transmitted all-optically through the network. During the offset time the control packet gets processed and the intermediate nodes ready there switch for the DB that follows. Figure 1.2 shows the concept of offset in OBS. Some of the issues that need special attention in OBS networks include burst assembly, contention resolution, signalling schemes, burst scheduling, and quality of service.

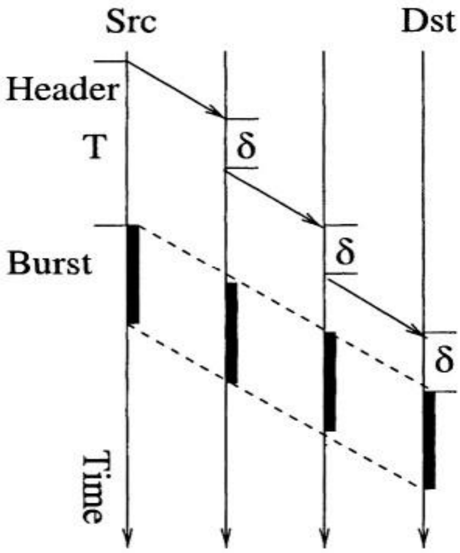

Fig 1.2 The use of offset time in OBS [1]

1.3 LAYOUT OF THE THESIS

In the following sections we get a clearer view of implementation of OBS in networks. In chapter 2 we will have an insight of major works in this area and the key motivation behind the project. In chapter 3 we will propose a MAC layer protocol to implement OBS in WDM ring network of TT-TR systems. In chapter 4 we analyse the performance of the proposed protocol and it with that of a TT-FR system. Finally we reach to a conclusion about the acceptability of the proposed protocol.

CHAPTER 2

LITERATURE REVIEW

2.1 LITERATURE SURVEY

The ever increasing size of data over the Internet has lead to an unprecedented rise in the demand for high speed and high capacity networks. This has been the motivation for the development of optical transmission systems. The two most talked about optical transmission systems these days are the Optical Packet Switched Networks and the Optical Burst Switched Networks.

Optical Packet Switching (OPS) [2] promises to provide an efficient and effective solution for carrying the huge volume of traffic in MANs. In case of OPS the control header and the payload data are scheduled to be transmitted on the same wavelength. Here the control header goes through an E/O conversion while transmission whereas while being processed it goes through an O/E conversion. The header is transmitted at a specific Sub-Carrier Multiplexing (SCM) tone. Usually in OPS the switches are expected to switch in nanoseconds but this strategy reduces the speed expectations for O/E/O conversions thereby making OPS realisable with present day technology. Nevertheless, with the available technology it is not possible to practically implement OPS in MANs or backbone networks as they need a large number of Fiber Delay Lines (FDLs), SCM header extraction and insertion schemes as well as packet synchronizers and O/E/O conversion devices[3].

Optical Burst Switching (OBS) [4][5][6] is being proposed an alternate manipulated way of implementing OPS in MANs bypassing some of the potential technological bottlenecks. In OBS each node maintains electronic buffers to store data destined to be delivered to specific nodes. When these data packets are processed, they are first assembled into data bursts. Then a control header containing all the control information corresponding to the data burst is generated and transmitted over the control channel, thereby reserving resources for the upcoming data burst. Then the data burst is transmitted all optically through the data channels and finally are disassembled at the destination node. In OBS only the control packets moving through the control channel undergo O/E/O conversion which is very less in contrast to OPS. The data bursts get transmitted all optically at each intermediate node. OBS provides higher bandwidth efficiency than Optical Circuit Switched networks and also provides statistical multiplexing at the optical layer. They do not require very high speed switches. So we can say OBS provides an effective all-optical network architecture that is practically possible with present day technology. In recent years, various researchers have come up with various implementations of OBS in WDM ring networks [7][10][12][13][15][16][17].

In [7][8][9], the authors implemented OBS in WDM ring networks where the network consisted of N nodes, and each node had a dedicated home wavelength for transmission. The nodes in the ring were FT-TR (fixed transmitter, tunable receiver) systems. As each node had a dedicated wavelength to transmit, this protocol successfully prevented channel collisions. However the occurrence of destination collision still prevailed as two source nodes might transmit to the same destination node. In such circumstances only one of the randomly selected data burst is received and the rest colliding bursts are dropped and hence lost. As some of the bursts may be lost, so the FT-TR systems are bandwidth inefficient. Moreover, such an OBS implementation in ring networks fails to provide a scalable and bandwidth-efficient solution for MANs since each individual wavelength is dedicated to the burst transmissions of its associated node.

Adopting an alternative approach, a distributed OBS metro ring architecture, designated LightRing, was reported in [10]. The LightRing multi-token Media Access Control (MAC) protocol is designed to reserve bandwidth to ensure the bandwidth-efficient and loss-free transmission of data bursts. Several Burst Assembly and Transmission (BAT) strategies capable of simultaneously assembling and scheduling bursts have been proposed. The OB-ADM architecture uses the same burst to transmit packets intended for different egress nodes by transmitting the burst with a High-level Data Link Control (HDLC) encoding for each packet in the burst and uses MPLS tags for each packet's destination. This approach ensures a lower latency in transmitting data bursts. Receiver collision problems can be resolved by allowing each OB-ADM node to equip with one fixed-tuned receiver and one fixed-tuned transmitter for each data wavelength. However, this architecture has the drawback of increasing the overall cost of the network. Furthermore, in LightRing, every burst must go through O/E and E/O conversion at each of the intermediate nodes. Therefore, LightRing is not sufficiently scalable to support hundreds of wavelengths since it requires more O/E/O conversion devices (i.e. one set for each wavelength) [11].

In the OBS ring network of tunable transmitter, fixed receiver (TT-FR) systems in [12][13], nodes were capable of transmitting on any wavelength but could receive only from the home wavelength. As each node received bursts only from the home wavelength, this implied there were no destination collisions. To solve the source contention, tokens were used. So only channel collision was to be addressed and a segmentation scheme was used to arbitrate after channel collision. In [14] a synchronous method was used to guarantee collision free operation but at the expense of low network throughput.

2.2 MOTIVATION

OBS ring networks based on a tunable transmitter, tunable receiver (TT-TR) were studied in [15][16][17]. The node architecture using TT-TR became a driving candidate because it can significant reductions in all the three types of collision. But still the collision rate remained high enough to rethink the scope for improvement. Considering the efficiency, of the node architecture. we continue to study the TTTR- based OBS ring networks and propose a MAC protocol for the same that hopefully further helps in avoiding collisions.

CHAPTER 3

IMPLEMENTING OBS IN TT-TR SYSTEMS

3.1 PROPOSAL

Having discussed the basics of Optical Burst Switching (OBS), we will now propose a MAC layer protocol to implement OBS in WDM Ring Networks for TT-TR systems using the JET signalling scheme. The TT-TR systems have a more complicated architecture than the TT-FR and FT-TR systems. This is because each node can transmit at any wavelength as well as receive data burst from all wavelengths. So, it is increasingly challenging to avoid channel and destination collisions in TT-TR systems. We will prove that the proposed protocol completely avoids source and channel collision, as well as minimizes destination collision to a great extent.

3.2 ASSUMPTIONS

Following are some of the assumptions for defining the MAC layer protocol.

- Let N be the number of nodes in the WDM ring network.
- Let W be the number of wavelength channels in the optical fibre such that, N>>W.
- One of the channels λ_0 is marked as Control Channel that carries the tokens, and rest are used as Data Channels.
- The number of tokens on the ring is equal to the number of data channels.
- Each node is equipped with a Tunable Transmitter and a Tunable Receiver.
- Each node maintains n-1 queues for every other node in the network.
- Size of the data burst is less than or equal to the ring delay (R).
- The size of each packet is fixed and the size of the data burst is also fixed.
- A node can transmit only one burst at a time.
- The clocks of all the nodes are synchronized.

- The inter-arrival times of the data packets follow an exponential distribution and the packets arrive at a constant rate of λ arrivals per unit time. The inter arrival time is given by

$$t = -\ln(y)/\lambda, \quad \text{where} \quad 0 < y < 1$$

We have used exponential distribution because of the continuous nature of the inter-arrival time. A node will generate a packet only if the present global time is greater than the sum of the previous packet generation time and the next inter-arrival time.

3.3 NODE ARCHITECTURE

In our proposed scheme a node can either transmit or receive at any point of time. Therefore, the maximum number of nodes that can be busy at any time is $\lfloor n/2 \rfloor$ (as other n/2 are transmitting). For maximum utilization of data channel, n>=w+2, [There will be atleast one node which can transmit and another node which can receive]. Tokens are evenly placed around the ring. Each node maintains a node status table and a channel status table. Node status table indicates the status of every other node in the network and the channel status table indicates the status of the data channels. Figure 1.4 and Figure 1.5 shows the structure of both tables. A channel can be reserved by a node only when the status of the channel in the CST is free i.e. 0. Each node entry in the NST has four attributes i.e. node status, start time for transmission, start time for reception, end time of transmission and end time of reception. The various node status possible are 00, 01, 10 and 11. Status 00 signifies that the node is free to transmit as well as receive. Status 01 signifies that the node is busy transmitting but is free to receive. Status 10 signifies that the node is free to transmit but is busy receiving. Status 11 signifies that the node is neither free to transmit nor receive.

A node can transmit only when it captures a token. It then converts the captured token into burst header. Destination node converts the burst header into free token and puts it onto the ring. Each node maintains n-1 queues for every other node in the network.

CHANNEL STATUS	START TIME (in sec)	ENDTIME (in sec)
λ 1 0/1		
. .		
λ w-1 0/1		

Status 0 => Busy Status 1 => Free

Fig 3.1 Channel Status Table

NODE STATUS	START TIME (T) (in sec)	START TIME (T) (in sec)	ENDTIME (T) (in sec)	ENDTIME (R) (in sec)
N_1 00/01/10/11				
. . .				
N_n 00/01/10/11				

Status 00 => Can both T and R Status 01 => Only T

Status 10 => Only R Status 11 => Neither T nor R

T-> Transmit R-> Receive

Fig 3.2 Node Status Table

3.4 THE PROTOCOL

At each instant of time a node performs a definite set of tasks that ensures synchronization between the following -

- control burst processing requests from predecessor nodes
- updation of the node status table
- updation of channel status table
- generation of packets to be transmitted to specific nodes
- burstification and transmission of bursts

Following is the sequence of steps followed by all the nodes in a parallel manner at each time instant.

Step 1 First each node checks whether or not there are any control burst headers waiting to be processed at this time instant.

- If yes and destination is busy, the control burst is dropped.
- If destination is free, then the burst header is processed and the NST and the CST corresponding to this node are updated.
- If the present node is the destination of the burst header, then it is released as free token after processing else it is forwarded to the next node.

Step 2 If at the present time instant a node completes its transmission, then the corresponding entries for source and destination in the NST are reset.

Step 3 If at the present time instant a node finds that a channel completes its transmission, then the corresponding entry in the CST is reset as well as the burst header is converted into token and released onto the control channel.

Step 4 Next the node checks whether or not it is free to transmit burst. If yes, it follows the following steps.

For data burst transmission a node first captures the token. A node on receiving a free token, checks the queue. If all the n-1 queues are empty then it transmits the free token onto the ring. For non-empty queue(s) it performs the following:

CASE 1 : For only one non-empty queue

If number of packets equal to the fixed burst size are available, it checks the destination node corresponding to this queue. If the destination is busy then it transmits the free token onto the ring. Otherwise it performs the following steps. First, it updates the entries corresponding to the destination node and the wavelength channel in the node status table and wavelength status table maintained at the node. The destination node and wavelength channel is set busy and the start time and end time of the burst is entered at the appropriate place. Next, the node converts the free token into burst header and transmits it onto the ring.

CASE 2 : More than one non-empty queues

Queues are searched in the order of arrival of the burst. The queue corresponding to the earliest arrival burst is searched first. If the destination node corresponding to this queue is free and number of packets equal to the fixed burst size are available, then the free token is processed as explained in step 1, else the next queue in the order of burst arrival is searched. This process continues until one of the destinations is free. Then we repeat the above steps for this request.

3.5 COLLISION PREVENTION ANALYSIS

The three types of collision that can take place in the ring network are Source, Destination and Channel. We will show that all these three collisions are minimised in our proposed scheme.

3.5.1 Source Collision

In the proposed scheme source collision does not take place as the node can transmit one burst at a time.

3.5.2 Channel Collision

Channel collision takes place, when bursts from different nodes are transmitted on the same channel. We will show that this does not take place. The prevention of channel collision in the proposed protocol is illustrated in Fig 3.3.

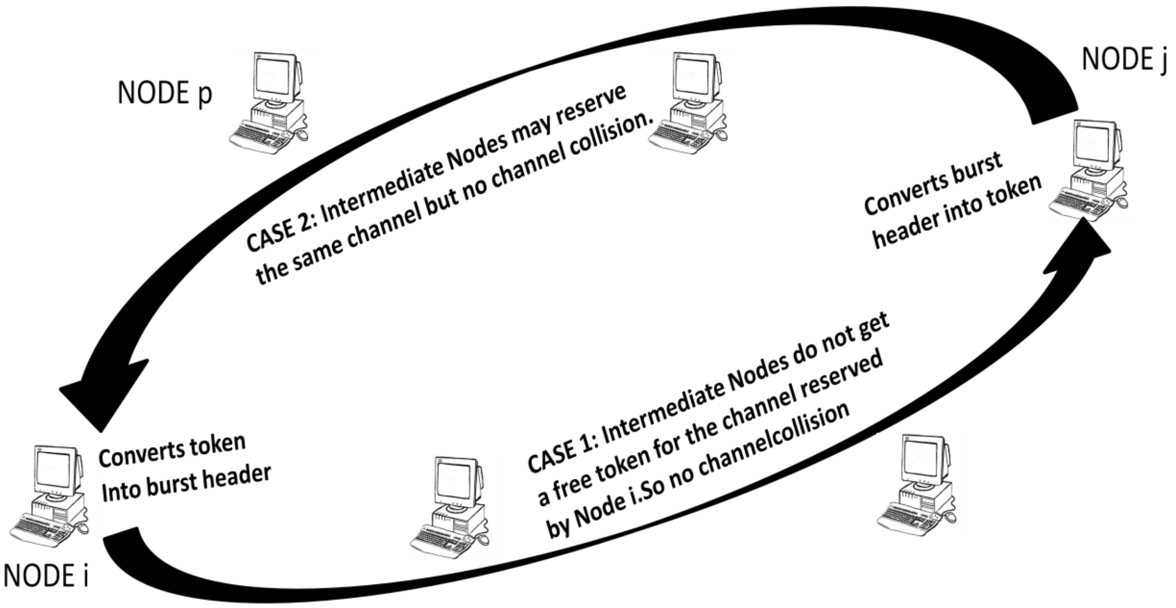

Fig 3.3 Prevention of Channel Collision

Assume that node i has a burst destined to node j. Let the start time t_s^i = T1 and the end time t_e^i = T2. Let the channel λ_k is selected for transmission. The entry corresponding to channel λ_k in CST of all nodes between i and j both inclusive is shown in Table 3.1. The entry corresponding to node i and node j in NST of all nodes between i and j both inclusive is shown in Table 3.2.

A node selects a wavelength channel only if it receives a free token corresponding to that channel. The intermediate nodes between source node i and destination node j receive a control burst, hence they cannot reserve wavelength λ_k. The free token corresponding to wavelength channel λ_k is converted to control burst at node i. Hence no channel collision takes place between node i and j.

CHANNEL STATUS		START TIME (in sec)	ENDTIME (in sec)
λ_1	0/1		
	. .		
λ_k	1	T1	T2
	. .		
λ_{w-1}			

Table 3.1 Entries of Updated Channel Status Table

NODE STATUS	START TIME (T) (in sec)	START TIME (R) (in sec)	ENDTIME(T) (in sec)	ENDTIME(R) (in sec)
N_1				
. .				
N_i 10	T1		T2	
. .				
N_j 01		T1		T2
. .				
N_n				

Table 3.2 Entries of Updated Node Status Table

The destination node j, after reserving necessary resources, releases a free token corresponding to wavelength λ_k. Any of the intermediate node say p, between node j to node i, can capture the free token corresponding to λ_k and transmit on wavelength channel λ_k. We will show that the transmission from node p on wavelength λ_k does not collide with the ongoing transmission from node i on channel λ_k.

Let the start time and end time of the burst from node p be t_s^p and t_e^p respectively. Let Δp be the propagation delay between node p and node i, collision takes place only iff

$$t_s^i < t_s^p + \Delta p < t_e^i < t_e^p + \Delta p$$

But we have assumed that the maximum burst size is equal to the propagation delay of the token around the ring

$$\Rightarrow \ t_e^i - t_s^i <= R$$

And we also deduce, $t_e^i <= t_s^i + R$

But $t_s^p + \Delta p >= t_s^i + R,$

$$\Rightarrow \ t_s^p + \Delta p >= t_e^i$$

This means, by the time the last bit of the burst from node p arrives at node i, the last bit from node i would have been transmitted. Hence the wavelength channel λ_k can be reserved by node p or any other intermediate node between node j and node i. Thus channel collision does not take place.

3.5.3 Destination Collision

Destination collision occurs when two nodes transmit to the same destination j. Let node i is transmitting to node j. The possibilities of destination collision has been illustrated in Figure 3.4. Destination collision occurs if some node other than i transmits to node j. There can be two cases viz.

- Such a node may exist between node i+1 and j-1.
- Such a node may exist between node j+1 and i-1.

Claim 1: There exist a node between nodes i+1 and j-1, whose communication to node j overlaps with that of i.

Proof: We prove by means of contradiction. Assume that such a node exists. That means there exists a node between i+1 and j-1 whose communication overlaps with node i. This

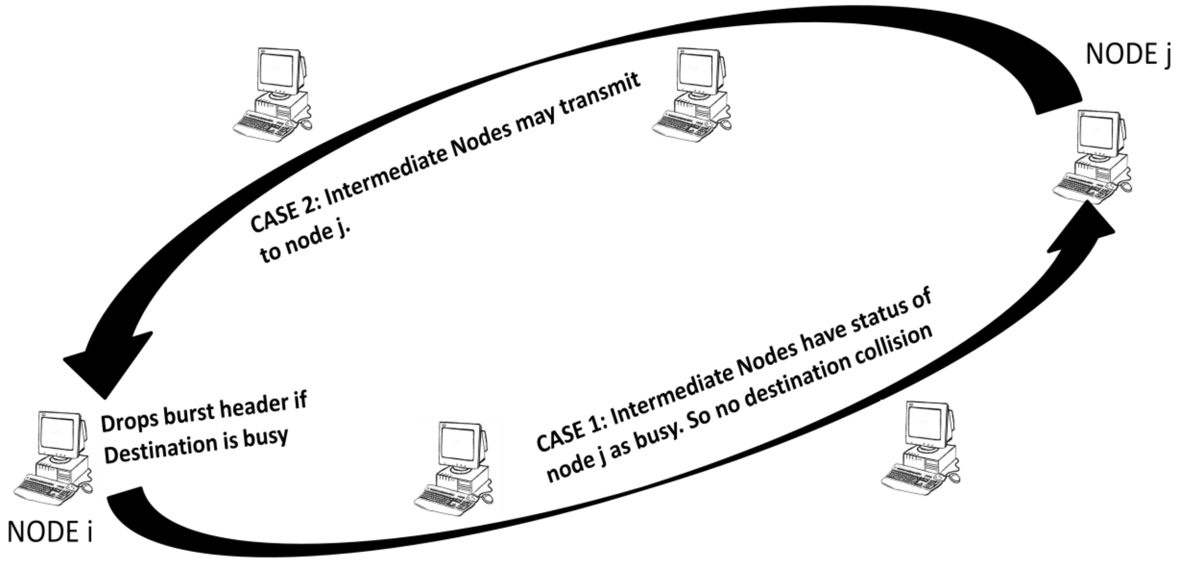

Fig 3.4 Possibilities of Destination Collision

contradicts our protocol i.e. a node will transmit to a destination, if and only if the destination is free. When there is ongoing transmission to node j from node i, no node will transmit to node j as the status of the destination node is already set to busy in the corresponding node status tables. This contradicts our assumption that there is some node between nodes i+1 and j-1 that transmits to node j and overlaps the transmission with node i.

Claim 2: Some node between j+1 and i-1 transmits to node j, which overlaps with the ongoing transmission from node i to node j, resulting in the destination collision.

Proof: Assume that there exist a node p between node j+1 and i-1 whose transmission overlaps with that of node i. Let t_s^p is the starting time of transmission of the burst from node p. Then, t_s^i i < t_s^p < t_e^i. The time at which the control burst is transmitted from node p be t_{cb}^p. Therefore the data burst will be transmitted after an offset time as we are following JET signalling scheme. So we can write,

$$t_s^p = t_{cb}^p + \text{offset}$$

Let δ be the propagation delay between node p and node i. Depending on the value of

$t_{cb}^p + \delta$, two cases arise.

1. $t_e^i > t_{cb}^p + \delta$

2. $t_e^i < t_{cb}^p + \delta$

In case (1), when the control packet arrives at node i, it will find that the destination node j is busy. Hence the control packet and the following data burst is dropped at node i. The control burst is converted into a free token and sent into the network. This sets the channel reserved by that data burst free.

In case (2), the data burst from node i is already transmitted and the destination node j is marked free in the NST of node i. As a result, resources are reserved for upcoming data burst and no contention takes place.

Thus the destination collision is greatly minimised.

3.6 CONCLUSION

Hence, the proposed MAC layer protocol for the TT-TR systems has been mathematically proved to be effective in avoiding source and channel collisions, and is also handy in reducing destination collision to a greater extent.

CHAPTER 4

RESULTS AND DISCUSSION

4.1 INTRODUCTION

In this chapter we analyse the results obtained by implementing an existing protocol for OBS in WDM ring network for TT-FR system as well as implement the proposed protocol for TT-TR systems. Then we compare the performance to find out whether the proposed protocol is better than the existing protocol for TT-FR systems. The comparison is done with respect to the following parameters.

- Number of Packets Lost
- Average Queuing Delay
- Average Propagation Delay

4.2 IMPLEMENTATION OF TT-FR SYSTEM

The ring network made up of TT-FR systems was simulated with the following assumptions.

- The number of nodes in the network is 12.
- The inter-arrival time of the packets follows exponential distribution with λ=0.9.
- The number of channels in the ring is 5. Out of this 4 are data channels and 1 is control channel.
- The size of the queues at each node is infinite (i.e. very large).
- The size of a packet is 1 second.
- The size of data burst is fixed i.e. 5second.
- Each nodes takes a constant time to process the control header.
- Propagation delay in each node is 1 second.

With the above assumptions, the TT-FR protocol was implemented and the number of packets lost, average queuing delay and average propagation delay was found out.

Table 4.1,4.2 and 4.3 show the values of these three attributes for three successive runs for different loads in terms of number of packets. Figure 4.1,4.2 and 4.3 show the corresponding plots.

LOAD	Packets Lost for 3 successive runs (TT-FR)			Mean Loss
50	15	15	10	13
100	35	30	25	30
150	45	45	45	45
200	60	65	65	63
250	80	75	85	80
300	90	95	95	93
350	115	110	120	115
400	135	130	130	131
450	140	145	145	143
500	165	160	165	163

Table 4.1 Number of Packets Lost in TT-FR

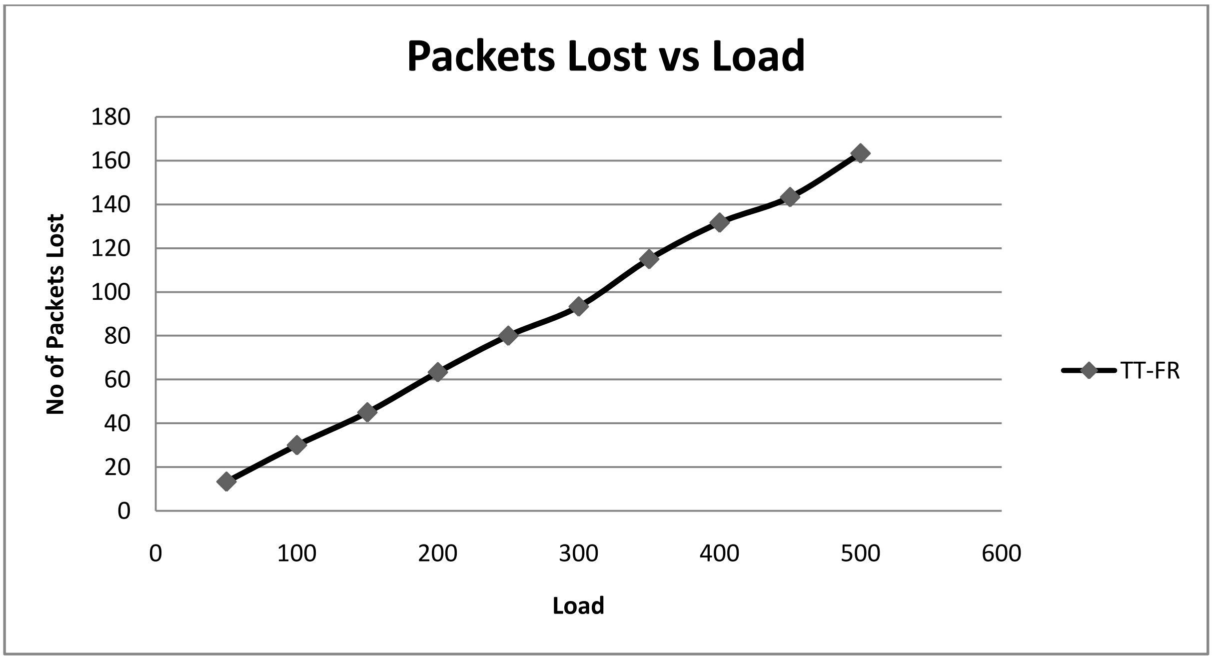

Fig 4.1 Packets Lost vs. Load (TT-FR)

LOAD	Queuing Delay for 3 successive runs (TT-FR)			Mean Queuing Delay
50	31	32	32	31.67
100	33	34	34	33.67
150	35	34	35	34.67
200	37	41	39	39
250	36	37	40	37.67
300	37	38	39	38
350	39	40	41	40
400	41	41	40	40.67
450	43	43	42	42.67
500	44	48	44	45.33

Table 4.2 Average Queuing Delay in TT-FR

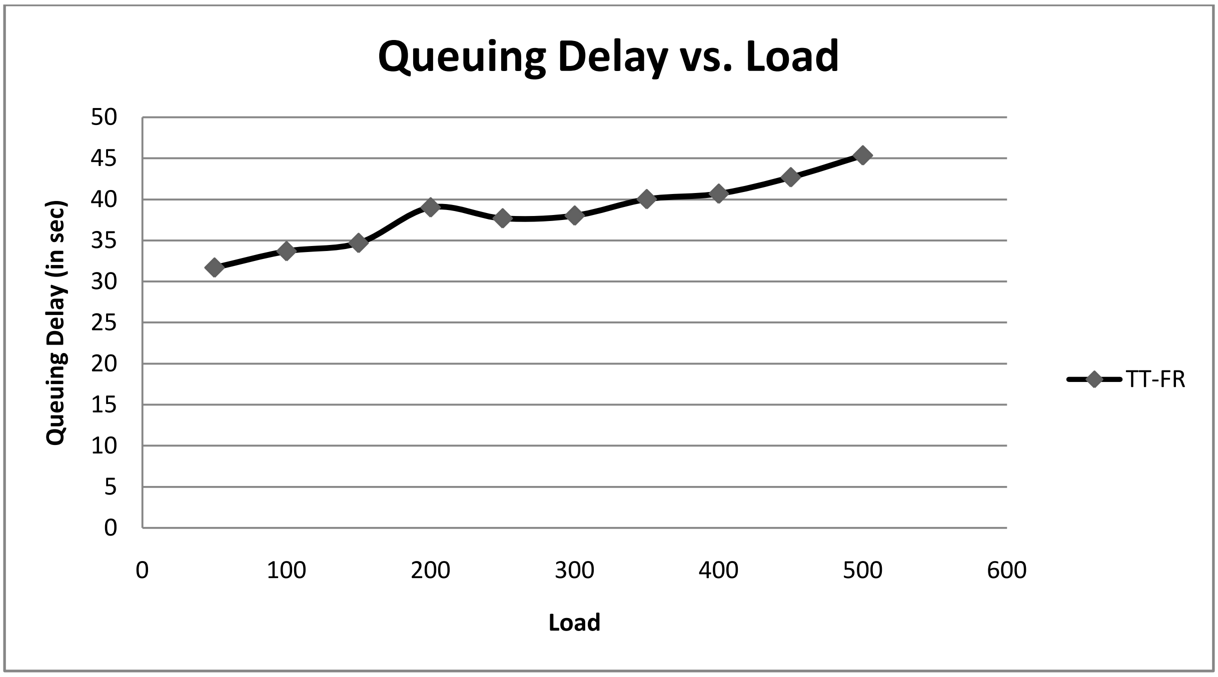

Fig 4.2 Average Queuing Delay vs. Load (TT-FR)

LOAD	Propagation Delay for successive 3 runs (TT-FR)			Mean Propagation Delay
50	4	5	4	4.33
100	4	5	4	4.33
150	4	4	5	4.33
200	4	3	4	3.67
250	4	4	4	4
300	3	4	5	4
350	4	4	4	4
400	4	4	5	4.33
450	5	4	4	4.33
500	4	4	4	4

Table 4.3 Average Propagation Delay in TT-FR

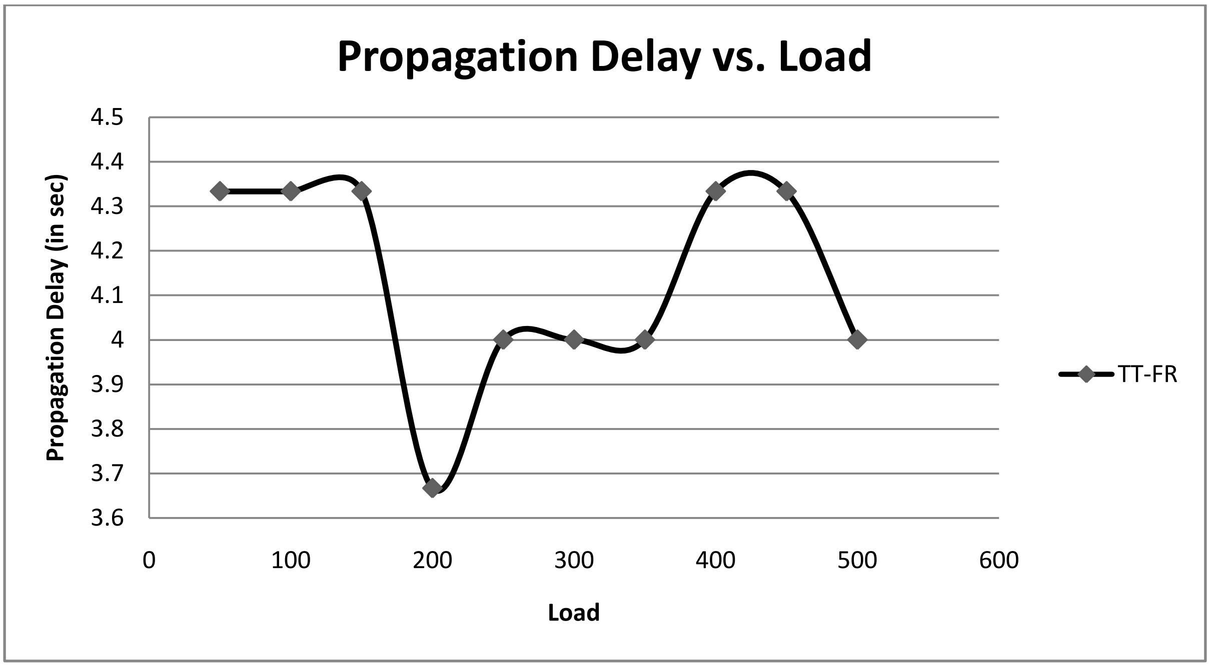

Fig 4.3 Average Propagation Delay vs. Load (TT-FR)

4.3 IMPLEMENTATION OF TT-TR SYSTEM

The proposed MAC layer protocol for TT-TR systems was implemented with the same assumptions as in TT-TR systems. Here also we measured the performance on the basis of the same three parameters i.e. packets lost, average queuing delay and average propagation delay.

Table 4.4,4.5 and 4.6 show the values of these three attributes for three successive runs for different loads in terms of number of packets. Figure 4.4,4.5 and 4.6 show the corresponding plots.

LOAD	Packets Lost for 3 successive runs (TT-TR)			Mean Loss
50	5	5	5	5
100	15	15	15	15
150	20	25	20	21.67
200	30	30	30	30
250	35	30	30	31.67
300	35	40	45	40
350	50	45	45	46.67
400	45	55	55	51.67
450	60	60	65	61.67
500	75	65	65	68.33

Table 4.4 Number of Packets Lost in TT-TR

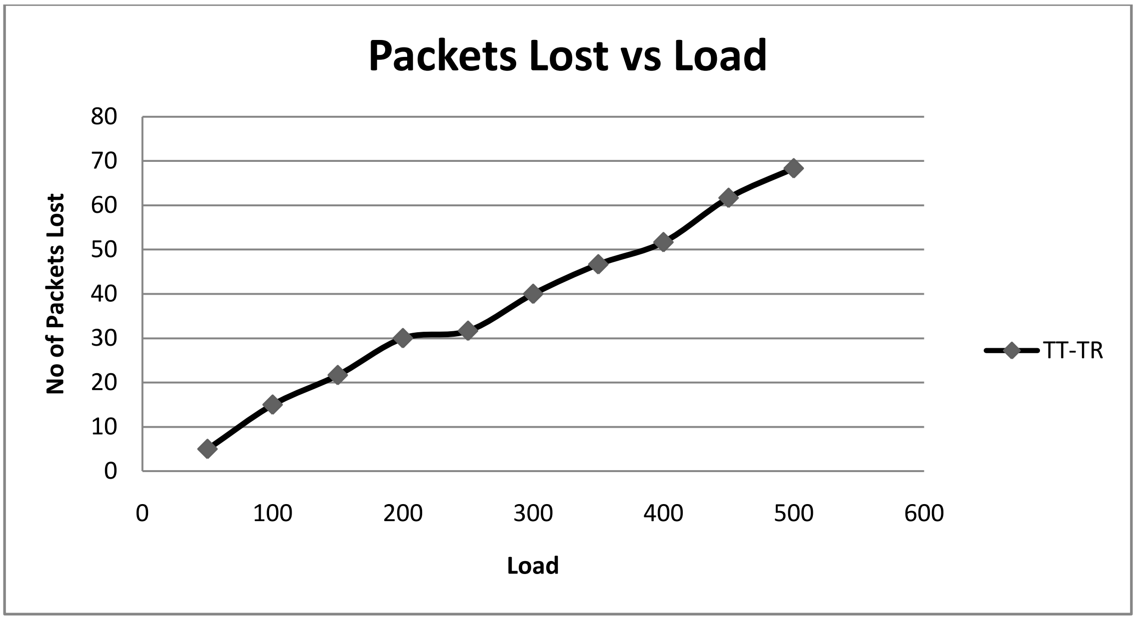

Fig 4.4 Packets Lost vs. Load (TT-TR)

LOAD	Queuing Delay for 3 successive runs (TT-TR)			Mean Queuing Delay
50	13	9	10	10.67
100	10	10	12	10.67
150	11	12	15	12.67
200	15	17	12	14.67
250	15	20	20	18.33
300	25	19	22	22
350	24	23	18	21.67
400	24	26	23	24.33
450	20	26	24	23.33
500	23	27	25	26.33

Table 4.5 Average Queuing Delay in TT-TR

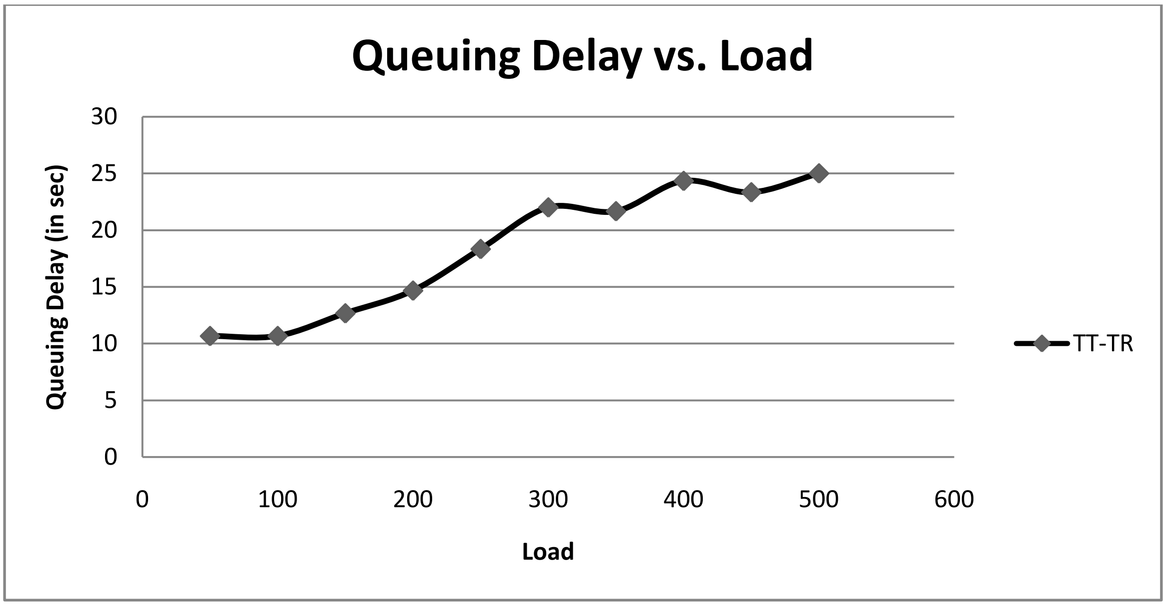

Fig 4.5 Average Queuing Delay vs. Load (TT-TR)

LOAD	Propagation Delay for 3 successive runs (TT-TR)			Mean Propagation Delay
50	4	4	4	4
100	5	4	4	4.33
150	4	4	4	4
200	3	4	4	3.67
250	4	4	4	4
300	4	4	4	4
350	3	4	4	3.67
400	4	4	4	4
450	4	4	4	4
500	3	4	4	3.67

Table 4.6 Average Propagation Delay in TT-TR

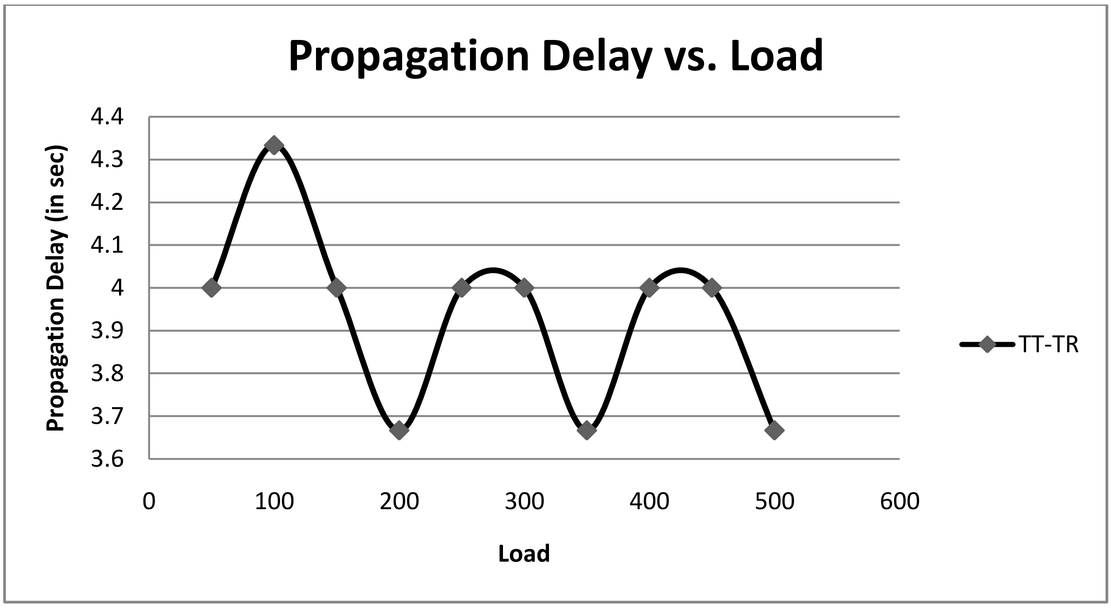

Fig 4.6 Average Propagation Delay vs. Load (TT-TR)

4.4 COMARISION OF TT-TR AND TT-FR SYSTEMS

Now we compare each parameter of the proposed TT-TR protocol with that of the existing TT-FR protocol. Figure 4.6, 4.7 and 4.8 show these comparisions.

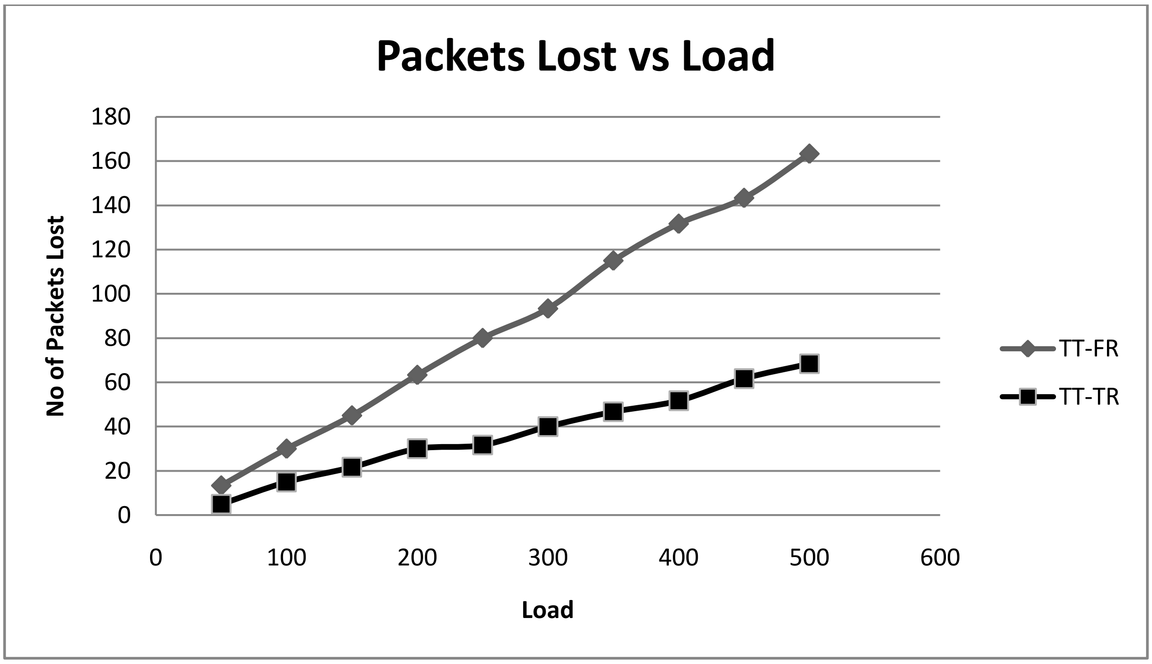

Fig 4.7 Packets Lost in TT-TR and TT-FR systems

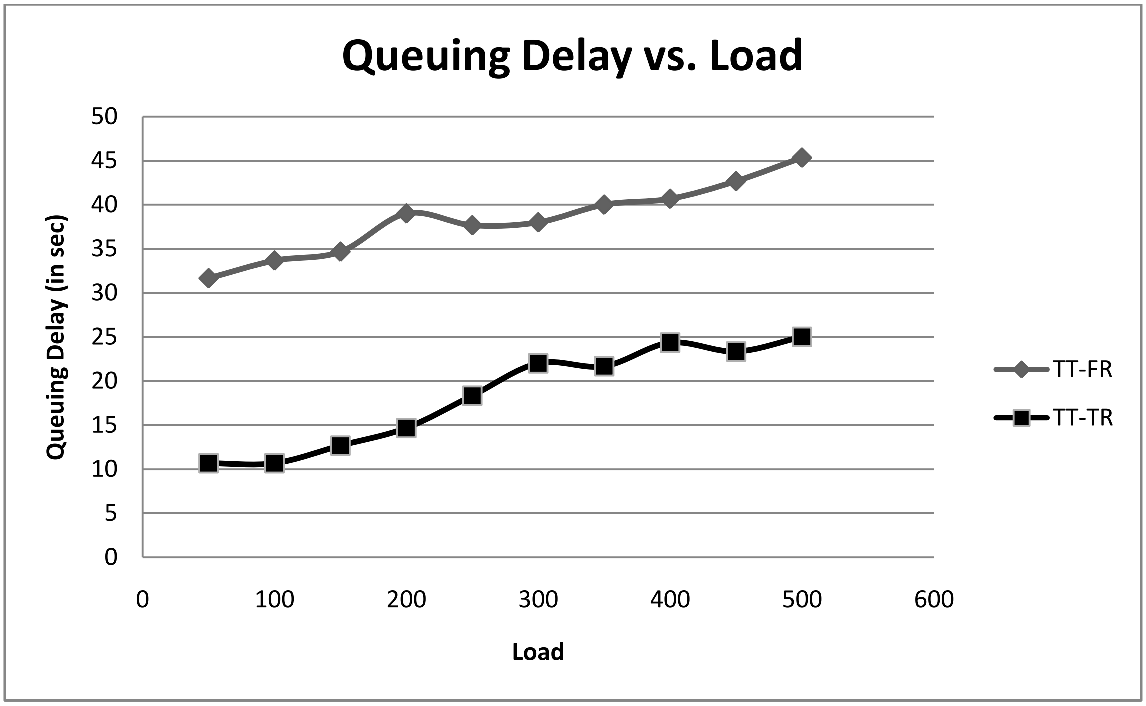

Fig 4.7 Queuing Delay in TT-TR and TT-FR systems

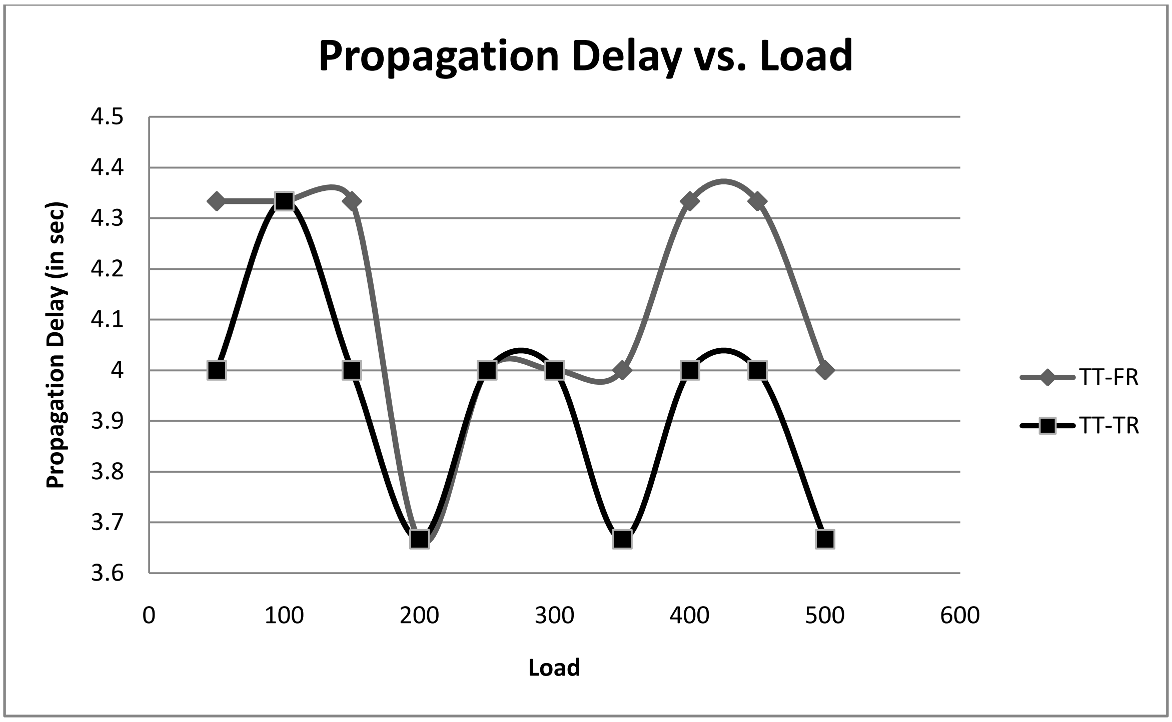

Fig 4.7 Propagation Delay in TT-TR and TT-FR systems

4.5 DISCUSSION

In case of packets lost, the graph of TT-FR is above that of TT-TR. This means the number of packets lost in the former case is more. For relatively less load the difference is less, but as the load increases the difference becomes more and more profound, Ultimately for large loads, TT-FR is almost unacceptable whereas loss in TT-TR is manageable. This clearly shows that the proposed TT-TR protocol is scalable in nature.

In case of average queuing delay, the TT-FR curve is way above that of TT-TR, showing that the packets in the former case suffer greater delay irrespective of the volume of load. The delay keeps increasing with increase in load for each system, but the difference is well maintained for all kinds of load.

The propagation delay for OBS networks remains almost constant as the data bursts are transmitted all optically. It depends only on the number of nodes in between the source and the destination. The average propagation delay for both TT-TR and TT-FR systems has been found to be 4 approximately.

CHAPTER 5

CONCLUSION

5.1 CONCLUSION

This study has proposed a MAC layer protocol to implement OBS in WDM ring network of TT-TR systems. In TT-TR, each node is equipped with a tunable transmitter and a tunable receiver. The node architecture using TT-TR makes efficient use of network resources such as bandwidth. However, it suffers from resource collision due to source, channel, and destination collision. This protocol has successfully eliminated source and channel collisions. Though destination collisions still exists but the probability of occurrence is low. We have also obtained a scalable network system as compared to the existing TT-FR systems. This scheme leads to low queuing delays while simultaneously achieving a high network throughput and thus improves the network performance significantly.

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